

# PATENT ABSTRACTS OF JAPAN

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(71)Applicant : MITSUBISHI KASEI CORP

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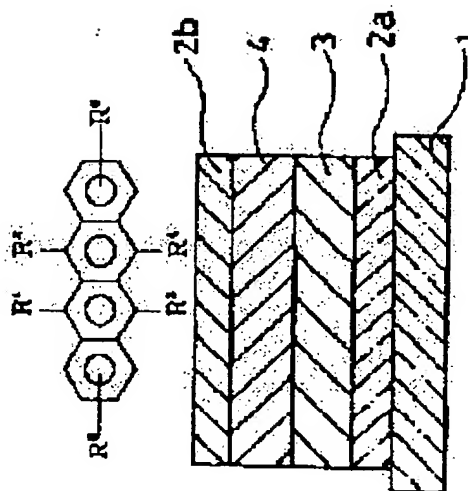
(72)Inventor : SATO YOSHIHARU  
KANAI HIROYUKI

## (54) ORGANIC ELECTROLUMINESCENT ELEMENT

### (57)Abstract:

**PURPOSE:** To improve luminescence performance and efficiency by laminating an anode, a hole injecting and transporting organic layer and an electron injecting and transporting org. layer on a base sheet.

**CONSTITUTION:** An anode 2a with a visible light transmittance of 60% or more and a thickness of 50-10,000 $\text{\AA}$ ;; a hole injecting and transporting org. layer 3 consisting of a naphthacene derive. of formula [ wherein R1 to R4 are each H, an alkyl, an aralkyl, an alkenyl, an allyl, an arom. hydrocarbon cyclic group which may have a substd. group, an arom. heterocyclic group, a halogen, an amide, an alkoxy(carbonyl), a nitro or an amino which may have a substd. group; R5 and R6 are each H, a halogen, an alkoxy(carbonyl) or an alkyl] and with a thickness of 100-3,000 $\text{\AA}$ ;; an electron injecting and transporting org. layer 4 consisting of the naphthacene deriv. and with a thickness of 100-2,000 $\text{\AA}$ ;; and a cathode 2b with a visible light transmittance of 60% or higher and a thickness of 50-10,000 $\text{\AA}$ ;; are laminated.



## LEGAL STATUS

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Japanese Patent No. 3196230

1. An organic electroluminescence element comprising:

an anode;

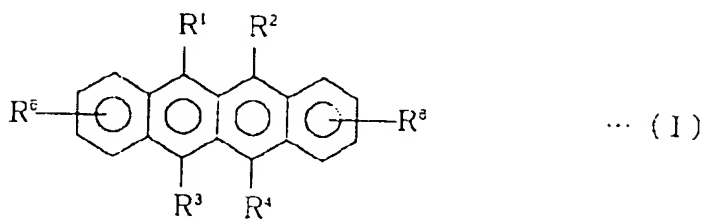
an organic hole injection and transport layer;

an organic electron injection and transport layer; and

a cathode, wherein

said anode, said organic hole injection and transport layer, said organic electron injection and transport layer, and said cathode are layered in that order, and

said organic hole injection and transport layer contains a naphthacene derivative represented by the following chemical formula (1).



[Chemical Formula (1)]

(In chemical formula (1), each of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  represents a hydrogen atom, an alkyl group, an aralkyl group, an alkenyl group, an allyl group, an aromatic hydrocarbocyclic group or an aromatic heterocyclic group which may contain a substituent,

a halogen atom, an amidogroup, an alkoxy group, an alkoxy carbonyl group, a nitro group, or an amino group which may contain a substituent; at least one of  $R^1 - R^4$  represents a halogen atom or an aromatic hydrocarbocyclic group which may contain a substituent; and each of  $R^5$  and  $R^6$  represents a hydrogen atom, a halogen atom, an alkoxy group, an alkoxy carbonyl group, or an alkyl group.)

2. An organic electroluminescence element according to claim 1, wherein a compound represented by said chemical formula (1) is contained in said organic hole injection and transport layer and in said organic electron injection and transport layer.

3. An organic electroluminescence element according to claim 1, wherein a compound represented by said chemical formula (1) is doped into a host material which is the organic hole injection and transport compound in said organic hole injection and transport layer.

4. An organic electroluminescence element according to claim 2, wherein a compound represented by said chemical formula (1) is doped into host materials which are the organic hole injection and transport compound in said organic hole injection and transport layer and the organic electron injection and transport

compound in said organic electron injection and transport layer.

5. An organic electroluminescence element according to either claim 3 or 4, wherein the amount of dope of the compound represented by said chemical formula (1) is  $10^{-3}$  mol% - 10 mol% with respect to the host material(s).

#### [Detailed Description of the Invention]

[0001]

#### [Field of Invention]

The present invention relates to an organic electroluminescence element, and more particularly to a thin film device which emits light upon application of an electric field through a combination of a hole injection and transport layer and an electron injection and transport layer each consisting of an organic compound.

[0002]

#### [Description of Conventional Art]

Conventionally, in a typical thin film electroluminescence element, structures are employed in which Mn or a rare earth element (Eu, Ce, Tb, Sm, etc.) which forms an emission center is doped into a II-VI family compound semiconductor such as ZnS, CaS, and SrS which is an inorganic material. However, electroluminescence elements created using

the inorganic materials described above suffer problems such as, for example, that (1) an alternating current drive is required (50 Hz - 1000 Hz), that (2) the drive voltage is high (~ 200 V), that (3) it is difficult to obtain a full color structure (in particular blue is problematic), and that (4) the cost for peripheral drive circuits is high.

[0003]

To this end, in order to solve the above problems, electroluminescence elements which use organic materials have recently been developed. In addition to anthracene, pyrene, etc. which have already been known as materials for an organic emissive layer, a cyanine dye (J. Chem. Soc., Chem. Commun., p. 557, 1985), pyrazoline (Mol. Crys. Liq. Cryst., Vol. 135, p. 355, 1986), perylene (Jpn. J. Appl. Phys., Vol. 25, p. L773, 1986), or a coumarin compound and tetraphenylbutadiene (Japanese Patent Laid-Open Publication No. Sho 57-51781) have been reported as materials for an organic emissive layer. In addition, in order to improve injection efficiency of carriers from electrodes to improve the emission efficiency, optimization of the types of electrodes, art for providing an emissive layer comprising a hole injection and transport layer and an organic fluorescent material (Japanese Patent Laid-Open Publication Nos. Sho 57-51781, Sho 59-194393, and Sho 63-295695 and Appl. Phys. Lett., Vol. 51, p. 913, 1987), etc., have been practiced.

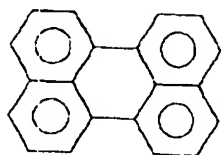
[0004]

In addition, in order to improve the emission efficiency of the element and simultaneously change the emission color thereof, doping of fluorescent materials for a laser such as coumarin into a host material of an aluminum complex of 8-hydroxyquinoline has also been performed (J. Appl. Phys., Vol. 65, p. 3610, 1989). However, there is a disadvantage that because the emission wavelength changes depending on the amount of dope, the amount of dope must be strictly controlled.

[0005]

Light emission by doping perylene (N1) or naphthacene (N2) represented by the following chemical formulae which are fused polycyclic aromatic compound into a host material of anthracene has also been reviewed (Jpn. J. Appl. Phys., Vol. 10, p. 527, 1971; Mol. Cryst. Liq. Cryst., Vol. 72, p. 113, 1981; and paper of the Institute of Electronics, Information and Communication Engineers, OME 89-48, 1989), but such structure has a high drive voltage and low emission brightness.

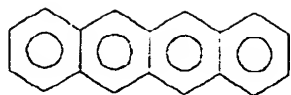
[0006]



... (N1)

[Chemical Formula (2)]

[0007]



... (N 2)

[Chemical Formula (3)]

[0008]

[Problem to be solved by the Invention]

As described, organic electroluminescence elements which have been disclosed suffer problems of insufficient emission characteristics, in particular, insufficient emission efficiency, and thus, further improvements are desired.

[0009]

The present invention was conceived to solve the above described problems and one object of the present invention is to provide an organic electroluminescence element which can be driven with a high emission efficiency.

[0010]

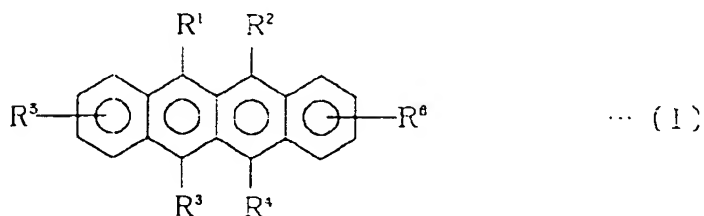
[Means for solving the problem]

In order to achieve at least the object mentioned above, according to one aspect of the present invention, there is provided an organic electroluminescence element comprising an anode; an organic hole injection and transport layer; an organic electron injection and transport layer; and a cathode, wherein the anode, the organic hole injection and transport layer, the



organic electron injection and transport layer, and the cathode are layered in that order, and the organic hole injection and transport layer or each of an organic hole injection and transport layer and the organic electron injection and transport layer contains a naphthalene derivative represented by the following chemical formula (1).

[0011]



[Chemical Formula (4)]

(in chemical formula (1), each of R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, and R<sup>4</sup> represents a hydrogen atom, an alkyl group, an aralkyl group, an alkenyl group, an allyl group, an aromatic hydrocarbocyclic group or an aromatic heterocyclic group which may contain a substituent, a halogen atom, an amidogroup, an alkoxy group, an alkoxy carbonyl group, a nitro group, or an amino group which may contain a substituent; at least one of R<sup>1</sup> - R<sup>4</sup> represents a halogen atom or an aromatic hydrocarbocyclic group which may contain a substituent; and each of R<sup>5</sup> and R<sup>6</sup> represents a hydrogen atom, a halogen atom, an alkoxy group, an alkoxy carbonyl group, or

an alkyl group.)

[0012]

More specifically, the present inventors have found, as a result of extensive study of organic electroluminescence elements which can be driven with a high emission efficiency, that it is preferable that an organic hole injection and transport layer or each of an organic hole injection and transport layer and an organic electron injection and transport layer contains a particular compound, and made the present invention.

[0013]

An organic electroluminescence element according to the present invention will now be described in more detail with reference to the accompanying diagrams.

[0014]

Fig. 1 is a cross sectional diagram showing an example structure of an organic electroluminescence element according to the present invention. In Fig. 1, reference numeral 1 represents a substrate, reference numerals 2a and 2b each represents a conductive layer, reference numeral 3 represents an organic hole injection and transport layer, and reference numeral 4 represents an organic electron injection and transport layer.

[0015]

The substrate 1 forms a supporting structure of the organic

electroluminescence element of the present invention and typically is made of a quartz or glass plate, a metal plate or metal film, or a plastic film or sheet. Of these, it is preferable to use the glass plate or a transparent synthetic resin substrate such as polyester, polymethyl methacrylate, polycarbonate, and polysulfone.

[0016]

Generally, a conductive layer 2a is provided on the substrate 1. The conductive layer 2a is made of a metal such as aluminum, gold, silver, nickel, palladium, and tellurium; a metal oxide such as an oxide of indium and/or tin; or a conductive resin such as copper iodide, carbon black, or poly(3-methylthiophene).

[0017]

In the example structure shown in Fig. 1, the conductive layer 2a functions as an anode to inject holes. On the other hand, the conductive layer 2b functions as a cathode to inject electrons into the organic electron injection and transport layer 4. As a material of the conductive layer 2b, materials similar to those for the conductive layer 2a as described above can be used, but, in order to efficiently inject electrons, it is preferable that a metal having a low work function is used. For example, it is preferable to use a suitable metal such as tin, magnesium, indium, aluminum, or silver, or an alloy of such

suitable metals.

[0018]

The formation of the conductive layers 2a and 2b is typically performed through sputtering or vacuum evaporation. In the case of metal fine particles such as silver or fine particles of conductive metal oxide or fine powders of conductive resin such as copper iodide and carbon black, however, it is also possible to form the conductive layers 2a and 2b by dispersing the powders into a suitable binder resin solution and applying the solution over the substrate. In addition, in the case of a conductive resin, it is also possible to form a thin film directly over the substrate through electrolytic polymerization. Each of the conductive layers 2a and 2b may also be a combined layer comprising layers of 2 or more materials.

[0019]

The thickness of the conductive layer 2a depends on the required transparency. When a high transparency is required, it is preferable to set the thickness so that the transmittance of visible light is 60% or greater, more preferably is 80% or greater. In this case, typically, the thickness is 50 Å to 10,000 Å and more preferably, approximately 100 Å to 5,000 Å. When the conductive layer 2a may have a low transparency, the material of the conductive layer 2a may be identical to that of the substrate 1 or the conductive layer 2a may be layered with a material

different from the materials for the conductive layer described above. On the other hand, the thickness of the conductive layer 2b is typically set at a value similar to the thickness of the conductive layer 2a.

[0020]

Although not shown in Fig. 1, a substrate similar to the substrate 1 may be further provided above the conductive layer 2b. However, as at least one of the conductive layers 2a and 2b must have a high transparency as an electroluminescence element, it is preferable that at least one of the conductive layers 2a and 2b has a thickness of 100 Å to 5,000 Å and has a high transparency.

[0021]

The organic hole injection and transport layer 3 provided on the conductive layer 2a must be formed of a compound that can efficiently transport holes in a direction from the anode to the organic electron injection and transport layer 4 when an electric field is applied between the electrodes. Therefore, as the organic hole injection and transport compound, the compound must be highly efficient in injecting holes from the conductive layer 2a and be able to efficiently transport the injected holes. To this end, a compound is desired that has a low ionization potential, a high hole mobility, a high stability, and characteristics such that impurities that form traps are

unlikely to be generated during manufacture or during use.

[0022]

Examples of such hole injection and transport compounds include the compounds described on pages 5 and 6 of Japanese Patent Laid-Open Publication No. Sho 59-194393 and on columns 13 and 14 of US Patent 4,175,960. Specific examples of these preferable compounds include aromatic amine compounds such as N-N'-diphenyl-N,N'-(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine; 1,1'-bis(4-di-p-tolylaminophenyl)cyclohexane; and 4,4'-bis(diphenylamino)quadrophenyl. In addition to the aromatic amine compounds, the example compounds include hydrazone compounds described in Japanese Patent Laid-Open Publication No. Hei 2-311591. These aromatic amine compounds or hydrazone compounds may be employed as a single entity or as various mixtures as necessary.

[0023]

The organic electron injection and transport layer 4 provided on the organic hole injection and transport layer 3 must be formed of a compound that can efficiently transport electrons in a direction from the cathode to the organic hole injection and transport layer when an electric field is applied between the electrodes. Therefore, as the organic electron injection and transport compound, the compound must be highly efficient in injecting electrons from the conductive layer 2b

and be able to efficiently transport the injected electrons. To this end, a compound is desired that has a high electron affinity, a high electron mobility, a high stability, and characteristics in which impurities that form traps are unlikely to be generated during manufacture or during use.

[0024]

Example materials that satisfy these conditions include aromatic compounds such as tetraphenylbutadiene (Japanese Patent Laid-Open Publication No. Sho 57-51781), metal complexes such as an aluminum complex of 8-hydroxyquinoline (Japanese Patent Laid-Open Publication No. Sho 59-194393), cyclopentadiene derivatives (Japanese Patent Laid-Open Publication No. Hei 2-289675), perynone derivatives (Japanese Patent Laid-Open Publication No. Hei 2-289676), oxadiazole derivatives (Japanese Patent Laid-Open Publication No. Hei 2-216791), bisstyrylbenzene derivatives (Japanese Patent Laid-Open Publication Nos. Hei 1-245087 and Hei 2-222484), perylene derivatives (Japanese Patent Laid-Open Publication Nos. Hei 2-189890 and Hei 3-791), coumarin derivatives (Japanese Patent Laid-Open Publication Nos. Hei 2-191694 and Hei 3-792), complexes of rare earth elements (Japanese Patent Laid-Open Publication No. Hei 1-256584), and distyrylpyrazine derivatives (Japanese Patent Laid-Open Publication No. Hei 2-252793). When these compounds are used, the organic electron injection and

transport layer functions to transport the electrons and, at the same time, to emit light upon recombination of holes and electrons.

[0025]

In an organic electroluminescence element according to the present invention, a naphthacene derivative represented by the chemical formula (1) is contained in an organic hole injection and transport layer or in each of an organic hole injection and transport layer and an organic electron injection and transport layer, each made of a material as described above. Normally, a naphthacene derivative represented by the chemical formula (1) is doped into the organic hole injection and transport layer 3 and the organic electron injection and transport layer 4 in a region near the boundary. The layer(s) to be doped is (are) the organic hole injection and transport layer 3 or the organic hole injection and transport layer 3 and the organic electron injection and transport layer 4, and may be a partial region of each layer. For example, as shown in Fig. 2, the layer to be doped may be a layer 3a of the organic hole injection and transport layer 3 near the boundary with the organic electron injection and transport layer 4, or, as shown in Fig. 3, the layers to be doped may be both the organic electron injection and transport layer 4 (4a) and the layer 3a of the organic hole injection and transport layer 3 near the boundary with the organic



electron injection and transport layer 4 (in Fig. 2 and 3, reference numerals 3a and 4a represent doped regions, reference numerals 3b and 4b represent undoped regions, and reference numerals 1, 2a, 2b, 3, and 4 each represents a layer identical to that shown in Fig. 1). The amount of dope of the naphthacene derivative with respect to the host material is preferably in the range of  $10^{-3}$  mol% to 10 mol%. In this description, the host material is the organic electron injection and transport compound as described above when the organic electron injection and transport layer 4 functions as the host, or, when the organic hole injection and transport layer 3 functions as the host, the host material is the aromatic amine compound, hydrazone compound, etc. as described above.

[0026]

In the above chemical formula (1), each of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  represents a hydrogen atom; a substituted or unsubstituted alkyl group such as: an alkyl group with the number of carbons of 1 - 6 such as a methyl group and an ethyl group; an alkoxyalkyl group such as a methoxyethyl group and an ethoxyethyl group; an alkoxyalkoxyalkyl group such as methoxethoxyethyl group and n-butoxyethoxyethyl group; an aryloxyalkyl group such as a phenyloxyethyl group, a naphthyloxyethyl group, and a p-chlorophenyloxyethyl group; an aryl alkyl group such as a benzyl group, a phenethyl group, a p-chlorobenzyl group, and

a p-nitrobenzyl group; a cycloalkylalkyl group such as a cyclohexylmethyl group, a cyclohexylethyl group, and a cyclopentylethyl group; an alkenyloxyalkyl group such as an allyloxyethyl group and a 3-bromoallyloxyethyl group; a cyanoalkyl group such as a cyanoethyl group and a cyanomethyl group; a hydroxyalkyl group such as a hydroxyethyl group and a hydroxymethyl group; and a tetrahydrofurylalkyl group such as a tetrahydrofuryl group and a tetrahydrofurylethyl group; a substituted or unsubstituted alkenyl group such as an allyl group and 2-chloroallyl group; a substituted or unsubstituted aryl group such as a phenyl group, a p-methylphenyl group, a naphthyl group, and an m-methoxyphenyl group; a cycloalkyl group such as a cyclohexyl group and a cyclopentyl group; a halogen atom such as a chlorine atom and a bromine atom; an amido group; an alkoxy group with the number of carbons of 1 - 6 such as a methoxy group and an ethoxy group; an alkoxycarbonyl group with the number of carbons of 1 - 6 such as a methoxycarbonyl group and an ethoxycarbonyl group; a nitro group; or an amino group which may contain a substituent. Preferably, each of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  is selected from a substituted or unsubstituted aryl group, a halogen atom, and a hydrogen atom. At least one of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$  represents a halogen atom or an aromatic hydrocarbocyclic group which may contain a substituent such as a substituted or unsubstituted aryl group.

[0027]

Each of  $R^5$  and  $R^6$  represents a hydrogen atom; a chlorine atom or a halogen atom; an alkoxy group with the number of carbons of 1 - 6 such as a methoxy group and an ethoxy group; an alkoxycarbonyl group with the number of carbons of 1 - 6 such as a methoxycarbonyl group and an ethoxycarbonyl group; an alkyl group with the number of carbons of 1 - 6 such as a methyl group and an ethyl group; an arylalkyl group such as a benzyl group, a phenethyl group, a p-chlorobenzyl group, and a p-nitrobenzyl group; a cycloalkylalkyl group such as a cyclohexylmethyl group, a cyclohexylethyl group, and a cyclopentylethyl group; an alkenyloxyalkyl group such as an allyloxyethyl group and 3-bromoallyloxyethyl group; or a cycloalkyl group such as a cyclopentyl group. Preferably, each of  $R^5$  and  $R^6$  is selected from a halogen atom, an alkoxy group with the number of carbons of 1 - 6, and an alkyl group with the number of carbons of 1 - 6.

[0028]

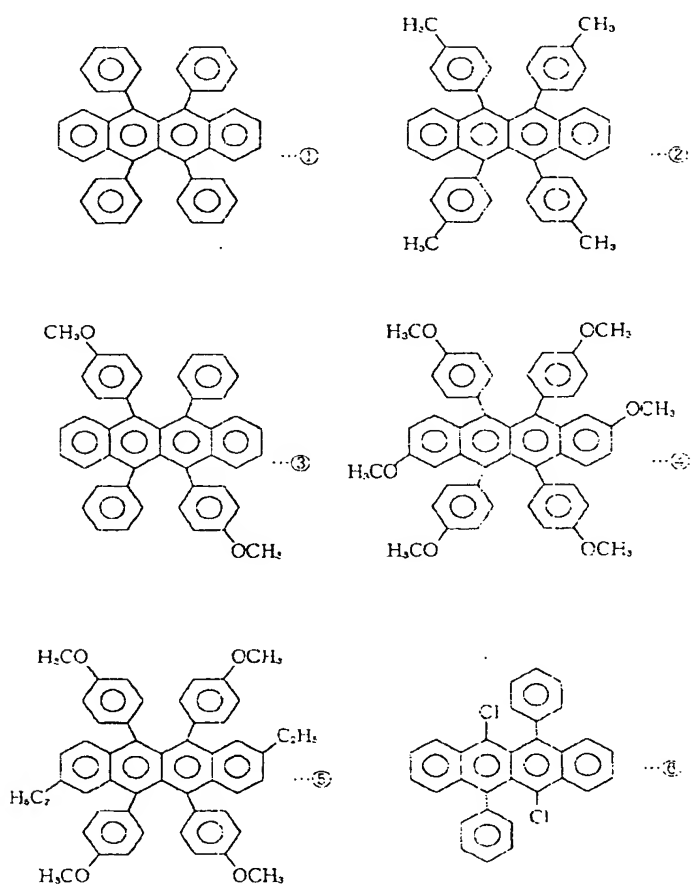
A method for synthesizing a naphthacene derivative according to the present invention is described in, for example, Copmt. Rend., Vol. 207, p. 585 (1938); Copmt. Rend., Vol. 240, p. 1113 (1955); Copmt. Rend., Vol. 239, p. 1101 (1954); Bull. Soc. Chim. France, p. 418 (1948); Bull. Soc. Chim. France, p. 155 (1952); Compt. Rend., Vol. 231, p. 5 (1950); Compt. Rend.,

Vol. 246, p. 661 (1958); Compt. Rend., Vol. 237, p. 621 (1953);  
 Compt. Rend., Vol. 232, p. 2233 (1951); J. Chem. Soc., p. 3151  
 (1954); Ann. Chim., Vol. 4, p. 365 (1959); and Tetrahedron Lett.  
 Vol. 29, p. 1359 (1988).

[0029]

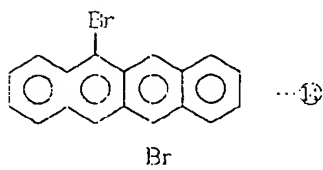
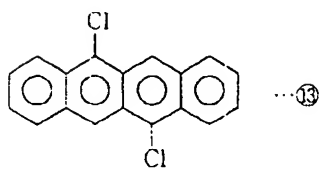
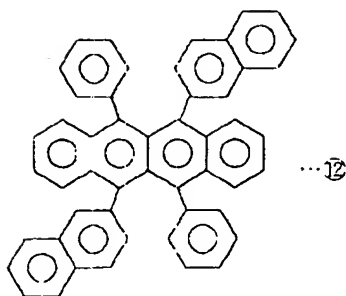
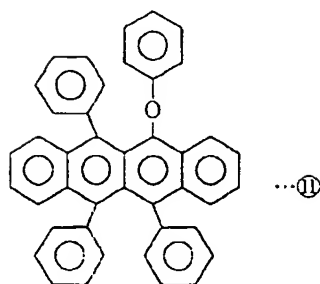
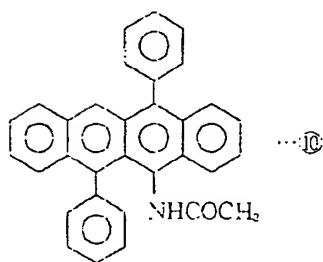
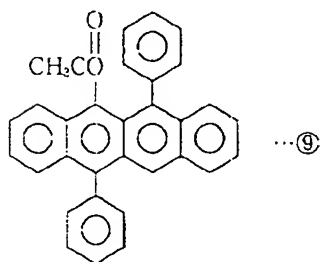
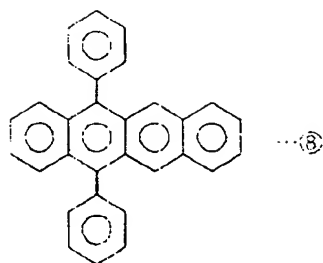
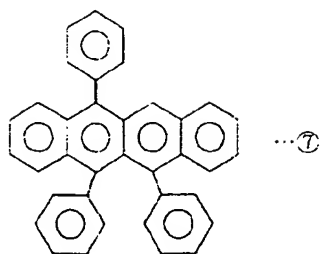
Specific examples of a naphthacene derivative represented  
 by the chemical formula (1) are shown below in chemical structural  
 formulae (1) through (14), although the naphthacene derivative  
 is not limited to these specific examples.

[0030]



[Chemical Formula 5]

[0031]



[Chemical Formula 6]

[0032]

According to the present invention, the organic hole

injection and transport layer 3 and the organic electron injection and transport layer 4 are formed by layering these layers on the conductive layer 2a, for example, through application or vacuum evaporation.

[0033]

In the case of the application, an application solution is prepared in which an organic hole injection and transport compound or an organic electron injection and transport compound and a naphthacene derivative represented by the chemical formula (1) is dissolved. An additive such as a binder resin and application characteristic improvement agent such as a leveling agent which does not form a trap for electrons and holes or a quenching agent for the light emission may also be added and dissolved as necessary. The application solution is then applied on the conductive layer 2a or on the organic hole injection and transport layer 3 through spin-coating or the like and dried so that the organic hole injection and transport layer 3 or the organic electron injection and transport layer 4 is formed. Examples of a binder resin include polycarbonate, polyarylate, and polyester. When the amount of addition of binder resin is large, the binder resin causes reduction in the electron mobility, and therefore, a smaller amount of addition is more preferable. A preferable amount is, for example, 50 weight% or less with respect to the application solution.

[0034]

In the case of vacuum evaporation, the organic hole injection and transport material or the organic electron injection and transport material is placed in a crucible provided in a vacuum container and a naphthacene derivative represented by the chemical formula (1) is placed in another crucible. After a vacuum of approximately  $10^{-6}$  Torr is created within the vacuum container using a suitable vacuum pump, both crucibles are simultaneously heated to vaporize the contained materials and an organic hole injection and transport layer 3 is formed on the substrate placed to oppose the crucibles, or, an organic electron injection and transport layer 4 is formed over the organic hole injection and transport layer 3 thus formed. As an alternative, it is also possible to mix, in advance, the above described materials in a predetermined ratio and to vaporize the mixture using the same crucible.

[0035]

The thickness of the organic hole injection and transport layer 3 formed through the process described above is typically 100 Å to 3000 Å, and is preferably between 300 Å and 1000 Å. Similarly, the thickness of the organic electron injection and transport layer 4 is typically 100 Å to 2000 Å and is preferably between 300 Å and 1000 Å. In order to evenly form these films each having such thin thickness, normally, vacuum evaporation

method is preferably employed.

[0036]

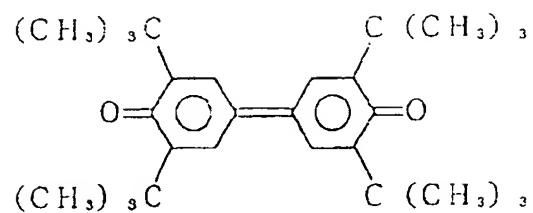
The method described above applies to a case wherein a naphthacene derivative represented by the chemical formula (1) is doped. In the case wherein the doping process is not performed, it is possible to form the layers in a similar manner without using a naphthacene derivative.

[0037]

In order to further improve the emission efficiency of the organic electroluminescence element, it is possible, as shown in Fig. 4, to layer another organic electron injection and transport layer 5 over the organic electron injection and transport layer 4 which is doped as described above. A compound used for the organic electron injection and transport layer 5 must satisfy the conditions that injection of electron from the cathode is easy and the electron transporting capability is even greater. Examples of such organic electron injection and transport material include a diphenylquinone derivative such as a compound represented by the following chemical formula (7), a perylene tetracarboxylic acid such as a compound represented by the following chemical formula (8) (Jpn. J. Appl. Phys., Vol. 27, p. L269, 1988), and an oxadiazole derivative such as a compound represented by the following chemical formula (9) (Appl. Phys. Lett., Vol. 55, p. 1489, 1989).

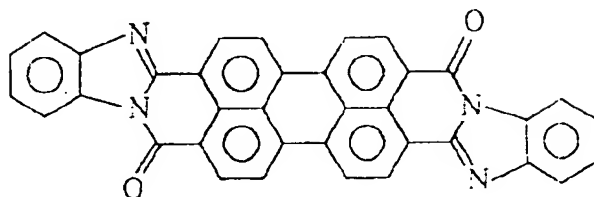


[0038]



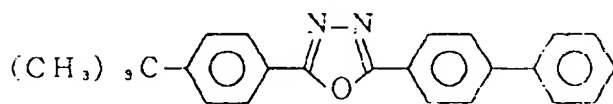
[Chemical Formula (7)]

[0039]



[Chemical Formula (8)]

[0040]



[Chemical Formula (9)]

[0041]

The thickness of such organic electron injection and transport layer 5 is typically 100 Å to 2000 Å, and is preferably 300 Å to 1000 Å.

[0042]

According to the present invention, it is possible to employ a structure opposite to the structure shown in Fig. 1, that is, a structure in which a conductive layer 2b, an organic electron injection and transport layer 4, an organic hole injection and transport layer 3, and a conductive layer 2a are layered on a substrate in that order. As discussed earlier, it is also possible to provide the organic electroluminescence element of the present invention between two substrates, at least one of which is highly transparent. Similarly, with regard to structures shown in Figs. 2, 3, and 4, it is possible to employ a structure in which the order of layering is reversed.

[0043]

[Operation]

By using a naphthacene derivative represented by the chemical formula (1) as a doping material for the organic hole injection and transport layer or for each of the organic hole injection and transport layer and the organic electron injection and transport layer of the organic electroluminescence element, it is possible to achieve superior emission characteristics.

[0044]

In order to improve the emission efficiency of the organic electroluminescence element and, at the same time, to change the emission color of the organic electroluminescence element,

various fluorescent dyes are doped into a host material of an aluminum complex of 8-hydroxyquinoline (US Patent 4,769,292). Advantages of this method includes that (1) emission efficiency is improved by a fluorescent dye of high efficiency, that (2) the emission wavelength can be varied by selecting the fluorescent dye, that (3) fluorescent dye which causes concentration quenching may be used, and that (4) fluorescent dye having inferior thin film characteristics may be used.

[0045]

According to an organic electroluminescence element of the present invention, holes and electrons injected from the anode and cathode recombine and excitons are generated. The fluorescent dye present in the region where the excitons spread collides with the excitons, is excited, and emits light. The region where the holes and electrons recombine can be considered to be near the boundary between the organic hole injection and transport layer 3 and the organic electron injection and transport layer 4. Therefore, it is preferable that the naphthacene derivative represented by the chemical formula (1) is doped in a region near the boundary between the organic hole injection and transport layer 3 and the organic electron injection and transport layer 4.

[0046]

[Examples]

The present invention will now be described in more detail with reference to examples and a comparative example. The present invention is not, however, limited to the examples described below as long as the structure is within the scope of the present invention.

[0047]

#### Example 1

An organic electroluminescence element having a structure as shown in Fig. 2 was prepared through the following processes.

[0048]

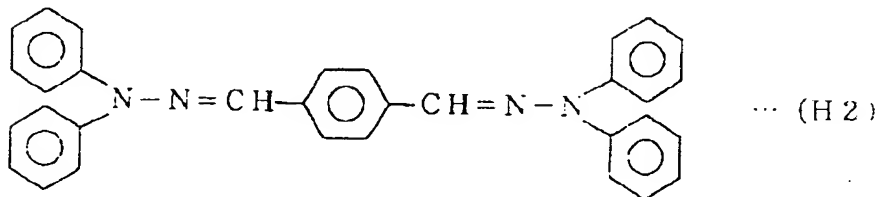
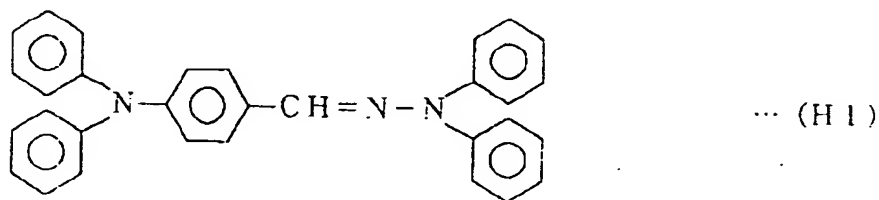
A glass substrate to which an indium tin oxide (ITO) transparent conductive film having a thickness of 1200 Å was deposited was washed by water, and then ultrasonically washed using isopropyl alcohol. Then, the substrate was placed in a vacuum evaporation device and a vacuum was created in the device using an oil diffusion pump so that the degree of vacuum within the device was  $2 \times 10^{-6}$  Torr or less. As a material for the organic hole injection and transport layer, a mixture of the following hydrazone compounds (H1) and (H2) mixed in a molar ratio (H1 : H2) of (1 : 0.3) was placed in a ceramic crucible and was heated using a tantalum wire heater around the crucible to vaporize the mixture within the vacuum container. The temperature of the crucible was in a range between 150 °C and 170 °C and the degree of vacuum during the evaporation was  $7 \times 10^{-7}$  Torr. The

organic hole injection and transport layer was thus evaporated with a thickness of 300 Å.

[0049]

Then, a naphthalene derivative (I) (rubrene) represented by the chemical formula (5) was heated simultaneously with the hydrazone compound using a crucible different from that for the hydrazone compound and was evaporated. In this manner, the organic hole injection and transport layer containing the naphthalene derivative (I) in 8.0 mol% was evaporated with a thickness of 200 Å.

[0050]



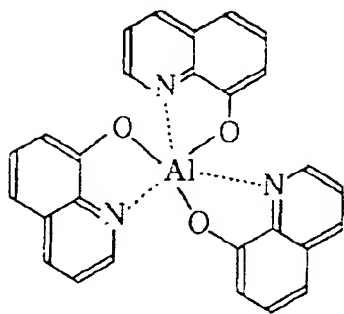
[Chemical Formula (10)]

[0051]

Then, as a material for an organic electron injection and transport layer, a 8 hydroxyquinoline complex of aluminum,  $\text{Al}(\text{C}_8\text{H}_6\text{NO})_3$ , represented by the following chemical structural

formula, was heated and evaporated so that an organic electron injection and transport layer composed only of the 8-hydroxyquinoline complex of aluminum was evaporated with a thickness of 720 Å.

[0052]



[Chemical Formula 11]

[0053]

Finally, as the cathode, an alloy electrode of magnesium and silver was evaporated and formed with a thickness of 1500 Å through dual simultaneous evaporation. The evaporation was performed using a molybdenum boat, with a degree of vacuum of  $8 \times 10^{-8}$  Torr, and for an evaporation period of 8 minutes. As a result, a glossy film was obtained. The atomic ratio between magnesium and silver was in a range between 10 : 1 to 10 : 2.

[0054]

In this manner, an organic electroluminescence element A was created.

[0055]

Results of measurements of emission characteristics measured when a positive DC voltage was applied to the ITO electrode (anode) and a negative DC voltage was applied to the magnesium-silver electrode (cathode) of the organic electroluminescence element A are shown in Table 1. The emission spectrum of the element A had a peak wavelength of 570 nm and the element A showed even emission of yellow color.

[0056]

In Table 1,  $V_{th}$  represents a voltage in which the brightness becomes  $1 \text{ cd/m}^2$ .

[0057]

#### Example 2

An organic electroluminescence element as shown in Fig. 3 was prepared as follows.

[0058]

An organic hole injection and transport layer made of the hydrazone compounds was evaporated onto a washed ITO glass substrate with a thickness of 300 Å in a manner similar to Example 1.

[0059]

Then, an organic hole injection and transport layer containing the naphthacene derivative (I) in an amount of 8.0 mol% was evaporated with a thickness of 200 Å similar to Example 1.

[0060]

Then, an 8-hydroxyquinoline complex of aluminum as a material for an organic hole injection and transport layer and the naphthacene derivative (I) as a fluorescent dye to be doped were evaporated through simultaneous heating using separate crucibles to obtain an organic electron injection and transport layer having a thickness of 840 Å and containing the naphthacene derivative (I) in a dope amount of 3.9 mol% with respect to the complex.

[0061]

Finally, a cathode was evaporated in a manner similar to Example 1 and an element B was obtained.

[0062]

The emission characteristics of the element B are shown in Table 1. The peak wavelength of the emission spectrum of the element B was 570 nm and even emission of yellow light was observed.

[0063]

Comparative Example 1

An organic electroluminescence element C was created through processes similar to Example 1 except that the naphthacene (I) was not doped into the organic hole injection and transport layer. The measurement results of the emission characteristics of the element C are shown in Table 1. The peak



wavelength of the emission spectrum of the element C was 530 nm and even light emission of green color was observed.

[0064]

STRUCTURE		ELEMENT	V <sub>th</sub> (V)	MAXIMUM BRIGHTNESS (cd/m <sup>2</sup> )	EMISSION EFFICIENCY (lm/W)
EXAMPLE	1	A	7	3261	0.513
	2	B	8	12700	1.037
COMPARATIVE EXAMPLE 1		C	9	2996	0.291

[Table 1]

[0065]

[Advantages]

As described, according to an organic electroluminescence element of the present invention, an anode, an organic hole injection and transport layer, an organic electron injection and transport layer, and a cathode are sequentially provided on a substrate and a particular naphthacene derivative is doped into the organic hole injection and transport layer or each of the organic hole injection and transport layer and the organic electron injection and transport layer, or into a portion of these layers. With such a structure, it is possible to obtain light emission having a brightness sufficient for practice with a low drive voltage when a voltage is applied to the electrodes. In addition, the initial emission characteristics can be maintained even after storage for a long period.

[0066]

The electroluminescence element according to the present invention can be applied in the field of flat panel displays (for example, wall-hung televisions), as light sources taking advantage of the characteristics as screen light emitting material (for example, a light source in a copier, a backlight source of liquid crystal displays and other instruments), and as display boards and marker lights, and thus, the industrial value of the element is significant.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a cross sectional view showing an embodiment of an organic electroluminescence element according to the present invention.

[Fig. 2] Fig. 2 is a cross sectional view showing another embodiment of an organic electroluminescence element according to the present invention.

[Fig. 3] Fig. 3 is a cross sectional view showing yet another embodiment of an organic electroluminescence element according to the present invention.

[Fig. 4] Fig. 4 is a cross sectional view showing still another embodiment of an organic electroluminescence element according to the present invention.

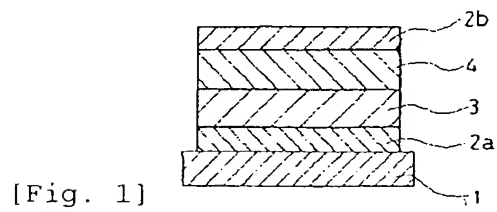
[Description of Reference Numerals]

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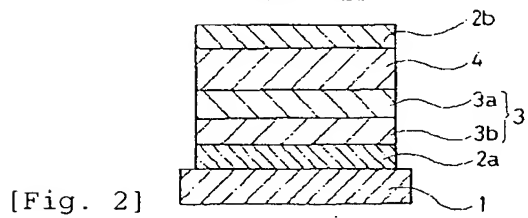
SUBSTRATE

- 2a, 2b CONDUCTIVE LAYER
- 3 ORGANIC HOLE INJECTION AND TRANSPORT LAYER
- 4 ORGANIC ELECTRON INJECTION AND TRANSPORT LAYER

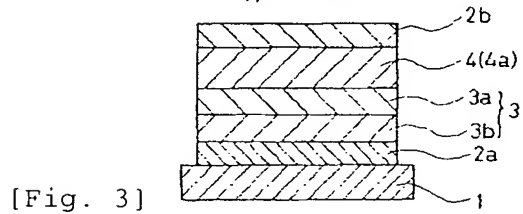
第 1 図



第 2 図



第 3 図



第 4 図

